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OWNERSHIP AND OPERATION OF TRENCH EXCAVATORS AND OTHER MECHANICAL EQUIPMENT BY THE WATER DEPARTMENT OF BALTIMORE[1]

BY V. BERNARD SIEMS[2]

HISTORICAL INFORMATION REGARDING THE USE OF MACHINERY BY THE BALTIMORE CITY WATER DEPARTMENT

Machinery for excavating earth and other material has been recognized for years as more economical and efficient than manual methods where conditions will permit the use of such mechanical equipment.

In order to complete the construction of water supply and sewerage systems in the cantonments during the world war as quickly as possible, the United States Army used machinery entirely, and the results obtained have, no doubt, had a great effect on the increased use of trench excavators, cranes and backfillers by contractors and municipalities. The writer used trenching machines, cranes and backfillers entirely for the construction of the water distribution system for Camp Meade and Camp Franklin in 1918. The distribution system of Camp Franklin and the enlargement of the Camp Meade system were completed in 2½ months. Machinery of all characters was used to construct the intake and pumping stations and to enlarge the filtration plant and balancing reservoirs at Camp Meade.

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[1] Presented before the Cleveland Convention, June 7, 1921.

[2] Principal Assistant Engineer, Water Department, Baltimore, Maryland.

In 1913 the engineers of the Baltimore City Water Department saw the necessity for obtaining a trenching machine, air compressor and pneumatic hammer to execute more expeditiously the work in connection with the installation of water mains. The Highways Department, in 1913, graded 33rd Street from Greenmount Avenue to Hillen Road, an approximate distance of 1.1 miles, preparatory to constructing a boulevard. The Water Department started the work of installing a 16-inch middle service water main by hand labor. As the cost of doing the work was exceeding the estimated amount appropriated, the Department engineers rented a trenching machine from the Consolidated Gas Company. With the use of this machine the work was rapidly pushed to completion and the cost was less than the amount actually appropriated. This rented machine excavated 2000 linear feet of trench, and the final cost showed that the excavating had been done at 16 cents a cubic yard. Based on this excellent showing, the Water Department was permitted to purchase a "Parsons" trench excavator, Model "K." Another important reason for permitting the purchase of a trenching

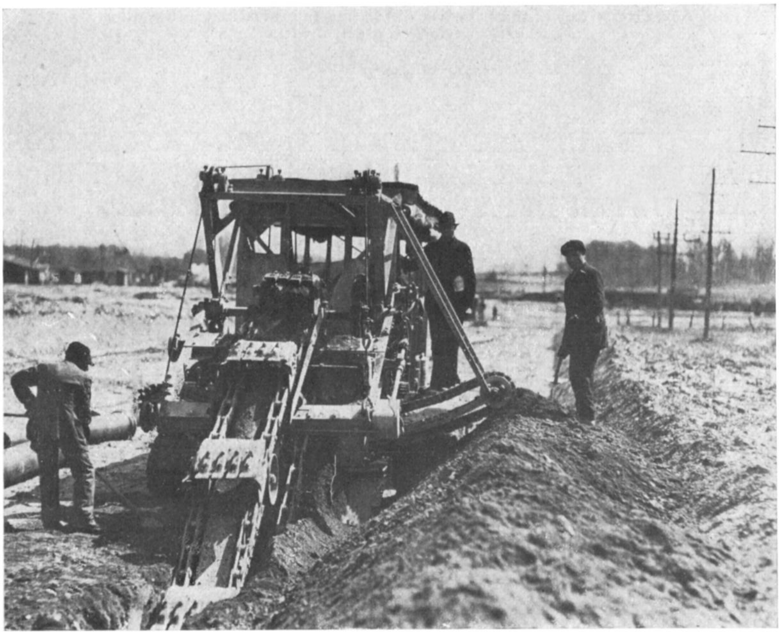


FIG. 1

machine was that the greater part of future water mains installations would be in the northeastern and northwestern sections of the city where few, if any, subsurface structures would be encountered, and conditions would be ideal for operating trenching machines. The normal corps of fifteen laborers was too small to permit constant operation of the trenching machine in the work of laying water mains and backfilling, and it was necessary to increase the number of men. In order to increase the amount of work even more and bring the water mains construction corps to the normal size of fifteen laborers, air compressors and pneumatic hammers were procured. This latter equipment was also necessary to secure uniform caulking of all pipe joints and, thereby, to decrease the probability of leaks occurring after the laying of improved paving. It also reduced the time, and consequently the cost of labor, in caulking.

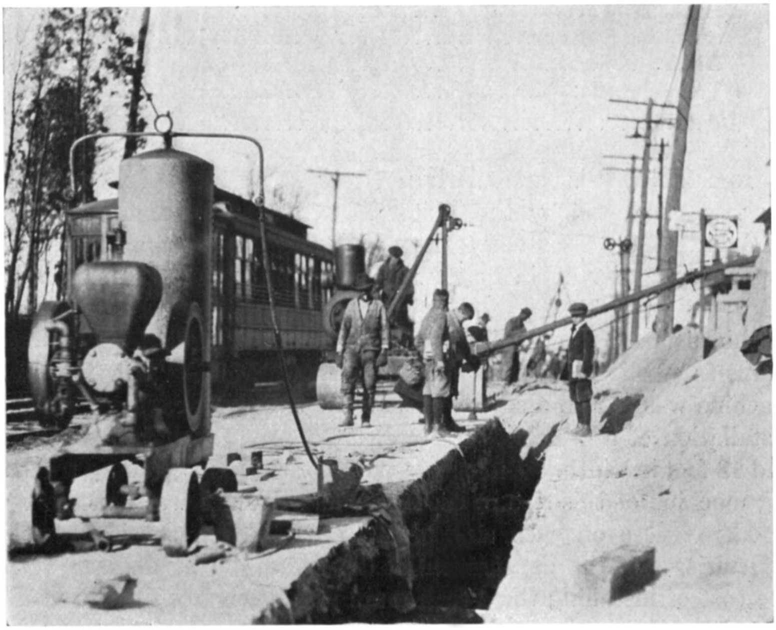


FIG. 2

The first air compressor purchased was of "Foster & Hosler" make and had a capacity of approximately 80 cubic feet. Considerable difficulty was experienced in training the caulkers to use the pneumatic hammers intelligently in order to prevent breaking the bells of cast iron pipe. Tests conducted over a long period showed that pneumatic hammers should operate under a long stroke and at a moderate working pressure of 40 pounds per square inch. The Engineering and Construction Division of the Water Department now has the following equipment:

Equipment	*Original cost*
4 Air compressors (ranging from 80 to 210 cubic feet capacity)	$8,189.00
2 Backfillers	3,488.00
1 Austin 5-ton crane	8,095.00
1 Ransome concrete mixer	802.00
1 Air piling hammer	275.00
10 Ditch pumps	3,447.00
3 Trenching machines	23,794.00
Total	$48,090.00

From table 1 it is particularly noticeable that most of the machinery was purchased by the Water Department between the years 1918 and 1920. This chart also shows the total equipment of the larger types of machinery now used by the Water Department. Since the year 1914 the Water Department has used trenching machines under almost all conditions in the installation of water mains in public highways. The "Parsons" Model "K" trenching machine was put to a severe test at one time in excavating for the installation of a 4-inch water main in a private alley between 10 and 12 feet in width. Difficulty was experienced in getting a trenching machine of this size in the alley, and damage was done to the wooden fences on each side of the alley. Even considering the difficulties and the expense entailed because of the damage done, the cost of installing the 4-inch main was much less than it would have been if done by manual labor. It may be interesting to note that a comparison of the cost of doing work in private alleys of various widths and public highways, whether done by manual labor or by trenching machine aided by hand labor, shows that the cost of the installation in private alleys is twice that of the cost in public highways. The Water Department, therefore, does not even consider the installation of water mains in private alleys. Judging from our records of cost, such installations should be discouraged by all municipalities.

Trenching machines have also been used to remove the cover of all sizes water mains where it has been found necessary to enlarge or replace them by other mains, particularly in cases where it is necessary to lower the water mains because of a change in the grade of the public highway. In the residential and business districts where it would be economical to excavate trenches with trenching machines for installation of water mains, accurate locations were obtained of water, gas and other services in advance of the work. The locations of these services were marked on the curb line, and the trenching machine operator very seldom disturbed any of them, as he raised the boom of the machine as it approached these marks. It was, of course, necessary to do the extra excavating around the service pipes by hand labor. In other instances the Department has found it economical to disconnect these services temporarily, in order to provide clearance for the operation of the trenching machine. Even with these additional costs, there was considerable economy in the use of the trenching machine, especially on the installation of large water mains. From our cost data records, it is estimated that damages to subsurface structures by the use of trenching machine approximate 1 per cent of the total cost of the installation of the water mains.

In 1918, due to the increasing number of extensions of water mains, the scarcity of labor and the high rate of pay necessary because of the salaries paid labor by industrial plants in and around Baltimore, it was decided to purchase additional trenching machines, a 5-ton "Austin" crane and backfillers. The cost of installing water mains was materially lessened by the use of this machinery in years 1919 and 1920. The 5-ton crane saved us considerable money, as we handled practically all cast iron water pipe and fittings of 20 inches and over with it. Two types of backfillers are used—one the boom drag and the other the scraper drag. The boom drag is used on the backfilling of trenches for large mains and the scraper drag on smaller mains in territories where the Highways Department will permit backfilling of ditches by puddling the material. We have, however, also used it in public highways where ramming was necessary. Tests made with mechanical tampers have not shown satisfactory results thus far. It is hoped that they will be developed to the extent of the other machinery now used by the Water Department. We have a much larger equipment of machinery than that noted on Table 1 in machines of a smaller character which we purchased from time to time and which are not shown on the table. I believe that the Water Department of the City of Baltimore ranks

TABLE 1

Method of ascertaining the cost per hour of operating machines

TYPE OF MACHINE (1)	DESIGNATED AS (2)	ORIGINAL COST (3)	PROBABLE LIFE (4)	DATE OF DELIVERY (5)	PROBABLE NO. OF HOURS IN OPERATION (6)	DEPRECIATION COST PER HOUR (7)	FUEL CONSUMED PER HOUR (8)	PROBABLE REPAIR COST PER HOUR (9)	TOTAL COST PER HOUR (10)	OPERATOR'S COST PER HOUR (11)	TOTAL OPERATING COST PER HOUR (12)
			years								
Air compressors											
Ingersoll-Rand	A. C. No. 1	$3,058	5	November 1920	2,000	$0.31	$0.61	$0.08	$1.00	$1.00	$2.00
Sullivan	A. C. No. 2	2,531	5	December 1920	2,000	0.25	0.61	0.09	0.95	1.00	1.95
2 Foster & Hosler	A. C. Nos. 3 and 4	1,300	5	March 1918	2,000	0.13	0.15	0.02	0.30	1.00	1.30
Backfillers:											
Backfiller M. 5	B. No. 1	847	5	October 1918	800	0.21	0.11	0.10	0.42	1.00	1.42
Backfiller M. 10	B. No. 2	2,641	5	October 1920	800	0.66	0.37	0.10	1.13	1.00	2.13
Crane:											
Austin	C. No. 1	8,095	5	August 1919	1,000	1.62	0.96	0.20	2.78	1.00	3.78
Concrete mixer:											
Ransome	C. M. No. 1	802	5	October 1920	800	1.00	0.23	0.02	1.25	1.00	2.25
Hammer:											
Air piling	A. H. No. 1	275	5	March 1920	250	0.22		0.03	0.25	1.00	1.25
Pumps:											
3—Novo 4 H. P.	P. No. 1	390	3	March 1919	2,000	0.07	0.19	0.04	0.30	1.00	1.30
3—Novo 2½ H. P.	P. No. 2	349	3	April 1919	2,000	0.06	0.19	0.04	0.29	1.00	1.29
1—Novo Centrifugal	P. No. 3	490	3	February 1919	2,000	0.08	0.19	0.04	0.31	1.00	1.31
1—Domestic	P. No. 4	180	3	February 1919	2,000	0.03	0.19	0.03	0.25	1.00	1.25
2—Schramm	P. No. 5	280	3	February 1919	2,000	0.05	0.19	0.04	0.28	1.00	1.28

Trenching machines:											
Parsons Model K.......	T. M. No. 1	5,542	5	April 1914	1,456		1.39	0.31	1.70	1.00	2.70
Parsons Model 24......	T. M. No. 2	8,052	5	December 1920	1,456	1.12	0.63	0.25	2.00	1.00	3.00
Parsons Model 36......	T. M. No. 3	10,200	5	April 1920	1,456	1.40	1.39	0.25	3.04	1.00	4.04

Columns 1, 2, 3, 4, 5, 6, 10, 11 and 12 are self-explanatory. Column 7—Column 3 divided by column 4 equals depreciation cost per year and this quotient divided by column 6 equals depreciation cost per hour. Column 8—Fuel consumed per hour ascertained by test on each machine and is approximately as follows: 90 per cent gasoline, 3 per cent grease and 7 per cent lubricating oil. Column 9—Yearly cost of repairs for each machine divided by column 6 equals repair cost per hour.

first among American municipalities in the use of machinery for doing the work in connection with the installation and maintenance of a water distribution system.

ORGANIZATION FOR OPERATING AND REPAIRING MECHANICAL EQUIPMENT

Figure 3 shows the organization of the operating and repair corps of mechanical equipment used by the Construction Subdivision of the Engineering and Construction Division. The automobile repairman, grade 1, in charge of mechanical equipment reports directly to the Assistant Civil Engineer in charge of the Construction Subdivision or his assistant, the same as the water pipe construction foremen do. The five automobile repairmen, grades 2 and 3, are subordinates assisted by handy-men. To each group equipment which they operate and maintain, is assigned.

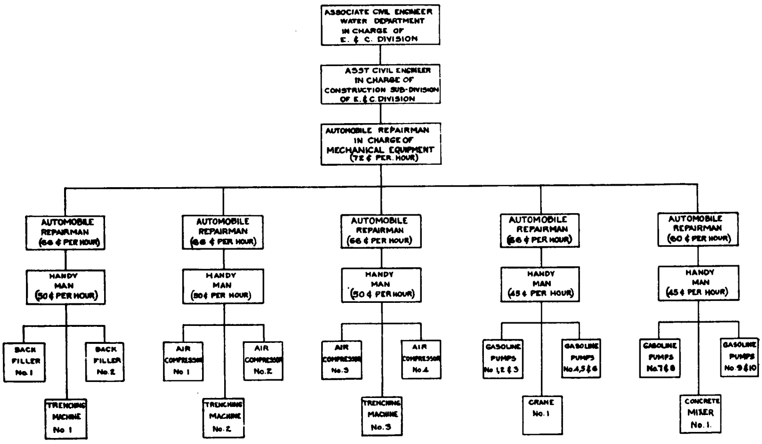

ASSOCIATE CIVIL ENGINEER WATER DEPARTMENT IN CHARGE OF E. & C. DIVISION
ASST CIVIL ENGINEER IN CHARGE OF CONSTRUCTION SUB-DIVISION OF E. & C. DIVISION
AUTOMOBILE REPAIRMAN IN CHARGE OF MECHANICAL EQUIPMENT (72 ¢ PER. HOUR)
AUTOMOBILE REPAIRMAN (66 ¢ PER HOUR)
AUTOMOBILE REPAIRMAN (66 ¢ PER HOUR)
AUTOMOBILE REPAIRMAN (66 ¢ PER HOUR)
AUTOMOBILE REPAIRMAN (66 ¢ PER HOUR)
AUTOMOBILE REPAIRMAN (60 ¢ PER HOUR)
HANDY MAN (50 ¢ PER HOUR)
HANDY MAN (50 ¢ PER HOUR)
HANDY MAN (50 ¢ PER HOUR)
HANDY MAN (45 ¢ PER HOUR)
HANDY MAN (45 ¢ PER HOUR)
BACK FILLER No. 1
BACK FILLER No. 2
TRENCHING MACHINE No. 1
AIR COMPRESSOR No 1
AIR COMPRESSOR No. 2
TRENCHING MACHINE No. 2
AIR COMPRESSOR No. 3
AIR COMPRESSOR No. 4
TRENCHING MACHINE No. 3
GASOLINE PUMPS No 1, 2 & 3
GASOLINE PUMPS No. 4, 5 & 6
CRANE No. 1
GASOLINE PUMPS No. 7 & 8
GASOLINE PUMPS No. 9 & 10
CONCRETE MIXER No. 1.

FIG. 3

The City Service Commission of Baltimore requires that an automobile repairman must have an elementary education, several years' experience in assembling or repairing and operating gas engines and other mechanical equipment. For handy-men it requires an elementary education, one year's experience as general handyman in a machine shop and ability to follow instructions from an automobile repairman. The handy-men are also used for burning out lead cast iron pipe bells on mains of the larger size. From experience it has been found that the best men available for positions of automobile repairmen are those advanced from the position of handy-man.

Experience in the use of mechanical equipment has proved to us that it is more economical and efficient to have a storage of duplicate mechanical parts available for any emergency than to order the repair parts when needed. The automobile repairman, grade 1, in charge of mechanical equipment is held responsible for stock parts of mechanical equipment and also for repairs to machinery. After the completion of the work the machinery is inspected thoroughly before being transported to another location, and, therefore, it is always in good working condition to commence the next work.

During winter months trenching machines, cranes, backfillers, air compressors, etc. are removed to the storage yards and completely overhauled. This is done only when there is no work on which this machinery can be used. The smaller gasoline pumps, melting furnaces, ground thawers, etc. are usually overhauled in the field.

COMPARISON OF COSTS—HAND LABOR VERSUS HAND LABOR AIDED BY MACHINERY

Curve 1 of figure 4 shows the comparison of labor cost per foot of installation of water mains by manual labor and manual labor aided by trenching machine. Referring to the table accompanying this curve, it will be seen that the percentage of economy obtained using a trenching machine with hand labor varies from 22.2 to 57.4 per cent. This percentage of saving is largely due to the intelligent placing of the laborers. For example with an average corps of fourteen men working with a trenching machine in the installation of a 6-inch water main, two laborers work on the surface to remove the material falling from the traveling buckets, three laborers are used to prepare the trench for pipe laying, two caulkers and two laborers pour the lead and caulk the joints, four laborers backfill the trench and ram the material, and one laborer attends to the lead melting furnace and keeps the water main installation corps supplied with tools. Such an organization will permit constant operation of a trenching machine throughout the working day.

The labor costs shown on curve 1 are average ones which include excavating and backfilling of trench, installation of the cast iron pipe and the overhead of the watchman and foreman. The standard dimensions of trench used by the Department are shown below curve 1. From experience we have found that four feet of cover will revent freezing and the pipe will not be affected by vibration caused by heavy motor vehicles.

Curve 2 of figure 4 shows the comparison of excavation cost per foot of installation of water main by manual labor and trenching machine aided by manual labor. The percentage of saving with the use of the trenching machine varies from 50 to 56.8 per cent. A trenching machine will excavate from 15 cubic yards an hour in 50 per cent rock and sandstone to 25 cubic yards an hour in loam, gravel and disintegrated rock.

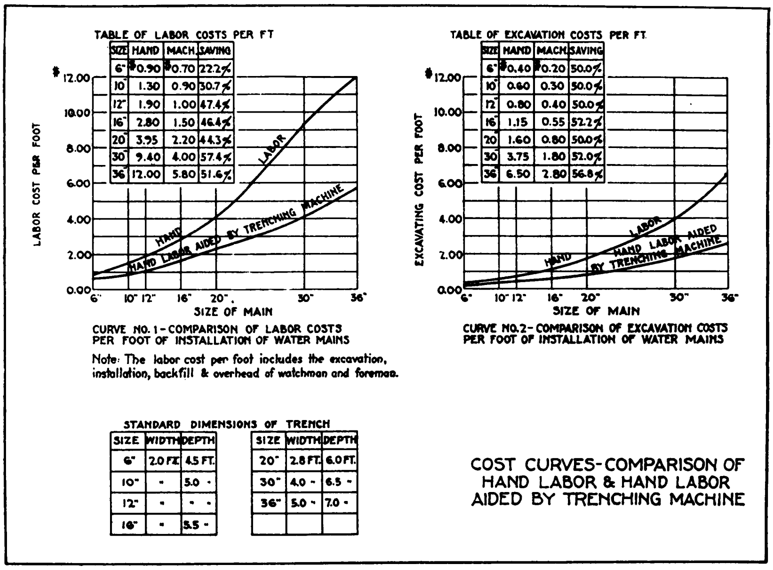


TABLE OF LABOR COSTS PER FT

SIZE	HAND	MACH.	SAVING
6"	$0.90	$0.70	22.2%
10"	1.30	0.90	30.7%
12"	1.90	1.00	47.4%
16"	2.80	1.50	46.4%
20"	3.95	2.20	44.3%
30"	9.40	4.00	57.4%
36"	12.00	5.80	51.6%

CURVE NO. 1 - COMPARISON OF LABOR COSTS PER FOOT OF INSTALLATION OF WATER MAINS

Note: The labor cost per foot includes the excavation, installation, backfill & overhead of watchman and foreman.

TABLE OF EXCAVATION COSTS PER FT.

SIZE	HAND	MACH.	SAVING
6"	$0.40	$0.20	50.0%
10"	0.60	0.30	50.0%
12"	0.80	0.40	50.0%
16"	1.15	0.55	52.2%
20"	1.60	0.80	50.0%
30"	3.75	1.80	52.0%
36"	6.50	2.80	56.8%

CURVE NO. 2 - COMPARISON OF EXCAVATION COSTS PER FOOT OF INSTALLATION OF WATER MAINS

STANDARD DIMENSIONS OF TRENCH

SIZE	WIDTH	DEPTH
6"	2.0 FT.	4.5 FT.
10"	"	5.0 "
12"	"	" "
16"	"	5.5 "

SIZE	WIDTH	DEPTH
20"	2.8 FT.	6.0 FT.
30"	4.0 "	6.5 "
36"	5.0 "	7.0 "

COST CURVES - COMPARISON OF HAND LABOR & HAND LABOR AIDED BY TRENCHING MACHINE

FIG. 4

Curve 3 of figure 5 shows the comparison of average number of feet of water main installed by a man a day by hand labor and by hand labor aided by trenching machine. The term "installed" includes the excavation for, installation and backfill of the water main. This curve shows the saving of time in the installation of water mains by the use of the trenching machine. Referring to the table above the curve you will see that the percentage of time saved varies from 33.3 to 80.0 per cent. For example, it will take a water pipe corps of fifteen men installing water mains without the use of a trenching machine ten days to excavate for, lay and backfill 300 feet of 20-inch main, whereas a pipe laying corps using a trenching machine to excavate the trench will complete the excavation, laying and backfilling of the 20-inch main in four days and two hours. Below this curve is a table of the standard dimensions of trench.

Curve 4 of figure 5 shows the average number of men the trenching machine replaces. This curve depicts the trenching machine as a labor saving device. Upon examining the curve and the table, you will find that the number of men replaced by the use of the trenching machine varies from 20 to 70 men. For an example, take a 6-inch main: The number of linear feet of trench excavated in one hour by the trenching machine is 60, but it would require 20 men to excavate the 60 feet of trench in one hour. The same principle applies to the other size mains, the table giving the number of men replaced by the trenching machine for water mains of every size. This curve and table were prepared from the average of a number of installations of water mains of each size noted upon the slide.

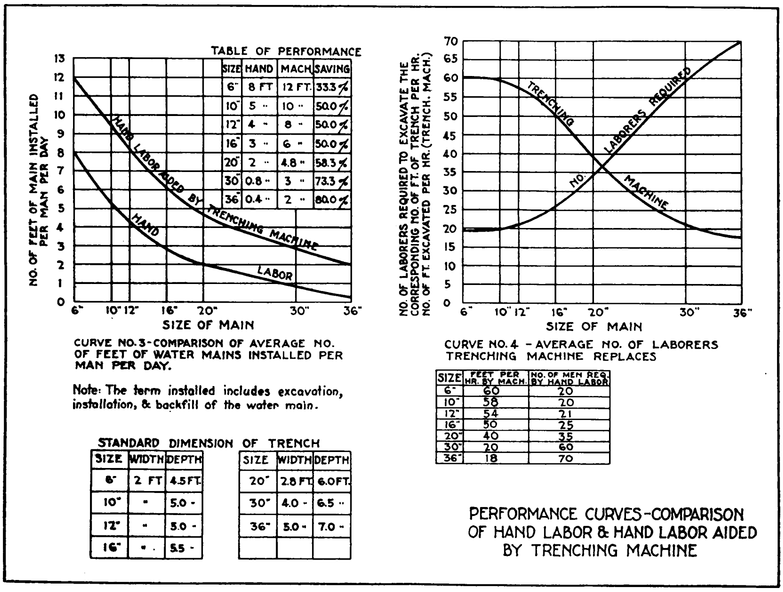


TABLE OF PERFORMANCE

SIZE	HAND	MACH.	SAVING
6"	8 FT	12 FT.	33.3%
10"	5 "	10 "	50.0%
12"	4 "	8 "	50.0%
16"	3 "	6 "	50.0%
20"	2 "	4.8 "	58.3%
30"	0.8 "	3 "	73.3%
36"	0.4 "	2 "	80.0%

CURVE NO. 3 - COMPARISON OF AVERAGE NO. OF FEET OF WATER MAINS INSTALLED PER MAN PER DAY.

Note: The term installed includes excavation, installation, & backfill of the water main.

STANDARD DIMENSION OF TRENCH

SIZE	WIDTH	DEPTH
6"	2 FT	4.5 FT.
10"	"	5.0 "
12"	"	5.0 "
16"	"	5.5 "

SIZE	WIDTH	DEPTH
20"	2.8 FT.	6.0 FT.
30"	4.0 "	6.5 "
36"	5.0 "	7.0 "

NO. OF LABORERS REQUIRED TO EXCAVATE THE CORRESPONDING NO. OF FT. OF TRENCH PER HR. NO. OF FT. EXCAVATED PER HR. (TRENCH. MACH.)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
TRENCHING MACHINE
NO. LABORERS REQUIRED
6"
10"
12"
16"
20"
30"
36"
SIZE OF MAIN

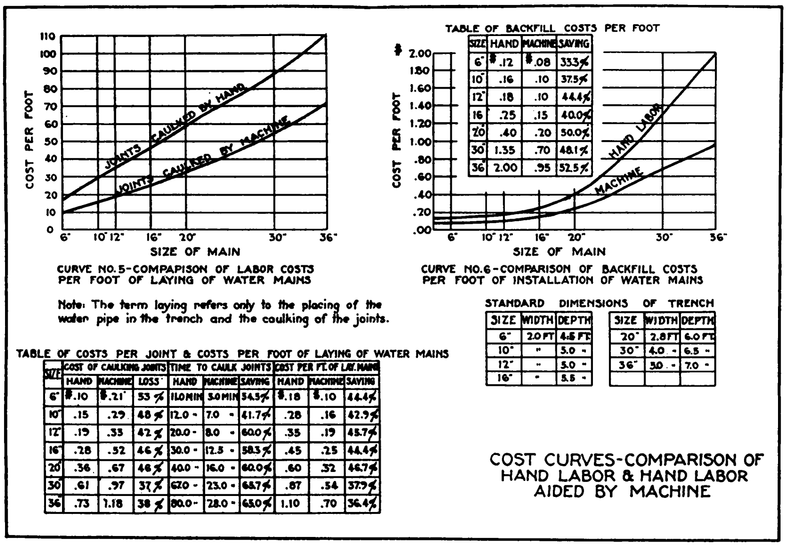
CURVE NO. 4 - AVERAGE NO. OF LABORERS TRENCHING MACHINE REPLACES

SIZE	FEET PER HR. BY MACH.	NO. OF MEN REQ. BY HAND LABOR
6"	60	20
10"	58	20
12"	54	21
16"	50	25
20"	40	35
30"	20	60
36"	18	70

PERFORMANCE CURVES - COMPARISON OF HAND LABOR & HAND LABOR AIDED BY TRENCHING MACHINE

Fig. 5

Curve 5 of figure 6 shows comparison of labor costs per foot of water mains between joints caulked by hand and those caulked with the use of pneumatic tools. The term "laying" refers only to the placing of the pipe in the trench and to the caulking of the joints. In the table of comparison of cost of caulking by hand and caulking with air hammers, you will notice that there is a loss varying from 37 to 53 per cent in favor of hand caulking but this loss is overcome by the saving in time varying from 41.7 to 65.7 per cent by caulking with air hammers, thus resulting in a saving of 36.4 to 46.7 per cent on the completed work.



CURVE NO. 5–COMPAPISON OF LABOR COSTS PER FOOT OF LAYING OF WATER MAINS

Note: The term laying refers only to the placing of the water pipe in the trench and the caulking of the joints.

TABLE OF COSTS PER JOINT & COSTS PER FOOT OF LAYING OF WATER MAINS

SIZE	COST OF CAULKING JOINTS			TIME TO CAULK JOINTS			COST PER FT. OF LAY. MAINS		
	HAND	MACHINE	LOSS	HAND	MACHINE	SAVING	HAND	MACHINE	SAVING
6"	$.10	$.21	53 %	11.0 MIN	5.0 MIN	54.5%	$.18	$.10	44.4%
10"	.15	.29	48 %	12.0 "	7.0 "	41.7%	.28	.16	42.9%
12"	.19	.33	42 %	20.0 "	8.0 "	60.0%	.35	.19	45.7%
16"	.28	.52	46 %	30.0 "	12.5 "	58.3%	.45	.25	44.4%
20"	.36	.67	46 %	40.0 "	16.0 "	60.0%	.60	.32	46.7%
30"	.61	.97	37 %	67.0 "	23.0 "	65.7%	.87	.54	37.9%
36"	.73	1.18	38 %	80.0 "	28.0 "	65.0%	1.10	.70	36.4%

TABLE OF BACKFILL COSTS PER FOOT

SIZE	HAND	MACHINE	SAVING
6"	$.12	$.08	33.3%
10"	.16	.10	37.5%
12"	.18	.10	44.4%
16"	.25	.15	40.0%
20"	.40	.20	50.0%
30"	1.35	.70	48.1%
36"	2.00	.95	52.5%

CURVE NO. 6–COMPARISON OF BACKFILL COSTS PER FOOT OF INSTALLATION OF WATER MAINS

STANDARD DIMENSIONS OF TRENCH

SIZE	WIDTH	DEPTH
6"	2.0 FT	4.5 FT
10"	"	5.0 "
12"	"	5.0 "
16"	"	5.5 "

SIZE	WIDTH	DEPTH
20"	2.8 FT	6.0 FT
30"	4.0 "	6.5 "
36"	5.0 "	7.0 "

COST CURVES–COMPARISON OF HAND LABOR & HAND LABOR AIDED BY MACHINE

Fig. 6

Curve 6 of figure 6 shows the comparison of backfill costs per foot of installation of water mains by hand labor and by backfiller. From the curve and tables you will find that the percentage of saving varies from 33.3 to 52.5 per cent. Below the curve is a table of the standard dimenions of trench.

In order to determine the effective depth to which lead could be compressed in the caulking of cast iron water pipe joints, research work was initiated at the Municipal Laboratory in 1914. The results of these tests showed that lead, like other engineering materials, has a distinctly characteristic curve. From this curve may be

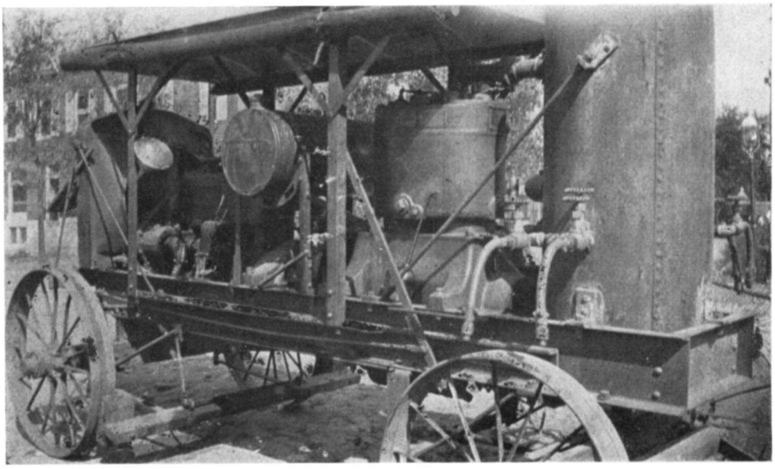


FIG. 7

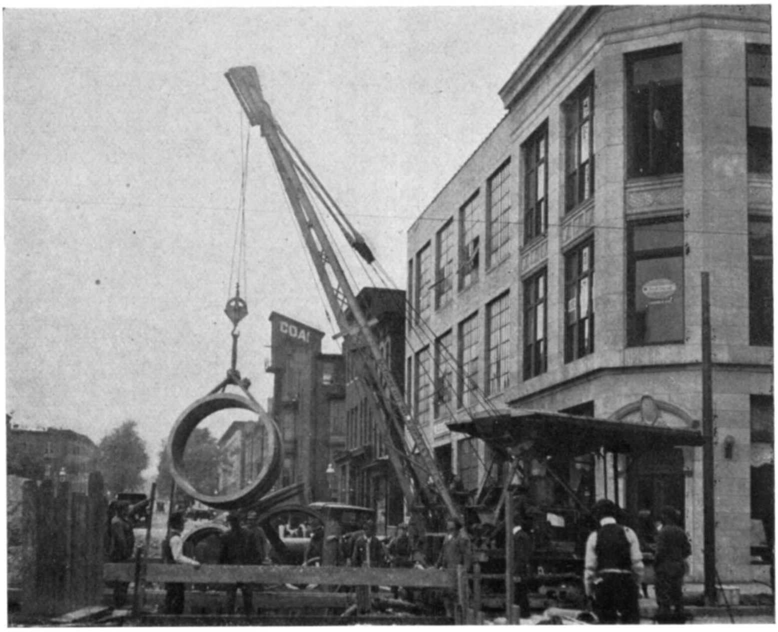


FIG. 8

found the greatest possible compression, which never exceeds $2\frac{1}{2}$ inches from the face of the bell, before the compressive molecular resistance of the lead itself equals or is greater than the strength of the cast iron in the sides of the pipe bells. When the latter is the case, there immediately follows a bursting of the pipe bell. It was recommended, therefore, that air compressors and pneumatic hammers operating under a long stroke and a moderate working pressure of 40 pounds per square inch be used on all the Department's caulking work.

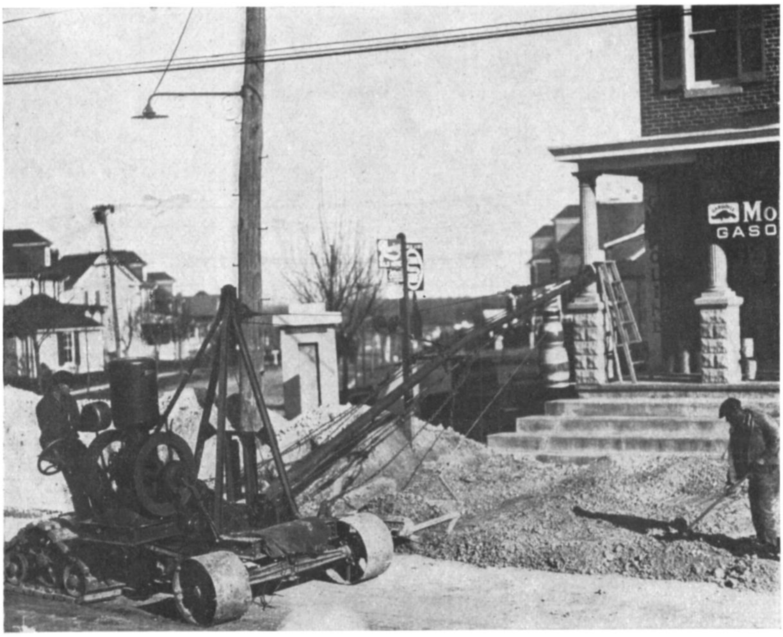


FIG. 9

A comparison of cost of the laying of water mains by hand labor and hand labor aided by crane on pipe 30 inches and larger shows that it cost $0.54 a foot to lay 30-inch pipe with hand labor aided by crane, and $0.95 a foot to lay by hand labor alone, or a saving of 43.1 per cent by using the crane. On 36-inch pipe it cost $0.70 a foot to lay with hand labor aided by crane, and $1.42 to lay with hand labor alone, or a saving of 50.7 per cent.

Table 1 shows the method of ascertaining the cost per hour of operating machinery. The explanation is given in the notes at bottom of the table.

Table 2 shows cost per foot of installation of water mains during part of years 1920 and 1921 by hand labor and by hand labor aided by trenching machine. The labor costs per foot (column 2) shown in this table include the cost of inserting small connections such as 6, 10 or 12 inch and the installation of 6, 10 and 12 inch valves at an average distance of 400 feet which constitutes the length of a city block. The same applies to the material cost per foot of installation of 6, 10 and 12 inch water mains (column 4). The columns are explained by the notes at the bottom of the table.

Table 3 shows the hourly rate of pay and water works material cost. An explanation is given in the notes at bottom of the table.

Table 4 shows methods of ascertaining depreciation charges on standard tools and equipment of water pipe construction foreman. These computations are the result of investigation of field conditions and are not assumptions. The depreciation charges are based upon a year of 300 working days.

Table 5 shows the methods of ascertaining the percentage of labor cost per foot of water mains installations covering loss and depreciation of tools. These results are explained by the notes.

Table 6 shows the method of ascertaining the overhead charge against each construction order. The Water Department consists primarily of the Engineering and Construction Division, Mechanical Division and Filtration Division. The Executive and Auditing Divisions are not considered separate as their entire operating cost is divided among the three above-mentioned divisions. The Construction Subdivision being one of three subdivisions of the Engineering and Construction Division, 11.11 per cent of the salaries of the Executive and Auditing Divisions of the Water Department, 33.33 per cent of the salaries of the executive and clerical forces of the Engineering and Construction Division, 100 per cent of the salaries of the engineers and clerks of the Construction Subdivision, the expenditure of the Bureau of Drafting for preparing Water Department plans and 11.11 per cent of the miscellaneous appropriations (buildings, equipment, automobiles, instruments, stationery, etc.) are charged to the Construction Subdivision as overhead. Dividing the total sum obtained as overhead by the total estimated expenditure of the Construction Subdivision, the percentage of overhead is obtained.

Table 7 shows the cost per foot of installation of water supply services, valves and fire hydrants, also standard dimensions of valve

TABLE 2

Cost per foot of installation of water mains part of years (1920 and 1921) by hand labor and hand labor aided by machinery

SIZE	HAND LABOR						HAND LABOR AIDED BY MACHINERY						
	Labor cost per foot	Miscellaneous cost per foot	Material cost per foot	Depreciation cost per foot	Overhead cost per foot	Total cost per foot	Labor cost per foot	Miscellaneous cost per foot	Material cost per foot	Depreciation cost per foot	Overhead cost per foot	Total cost per foot	CONDITION OF SUBSURFACE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
inches													
6	$1.85	$0.10	$1.70	$0.19	$0.38	$4.22	$1.30	$0.10	$1.70	$0.13	$0.32	$3.55	Maximum
6	0.90	0.10	1.70	0.09	0.28	3.07	0.70	0.10	1.70	0.07	0.26	2.83	Average
6	0.55	0.10	1.70	0.06	0.24	2.65	0.40	0.10	1.70	0.04	0.22	2.46	Minimum
10	2.60	0.13	2.60	0.26	0.56	6.15	1.80	0.13	2.60	0.18	0.47	5.18	Maximum
10	1.30	0.13	2.60	0.13	0.42	4.58	0.90	0.13	2.60	0.09	0.37	4.09	Average
10	0.90	0.13	2.60	0.09	0.37	4.09	0.55	0.13	2.60	0.06	0.33	3.67	Minimum
12	2.85	0.15	3.25	0.29	0.65	7.19	2.10	0.15	3.25	0.21	0.57	6.28	Maximum
12	1.90	0.15	3.25	0.19	0.55	6.04	1.00	0.15	3.25	0.10	0.45	4.95	Average
12	1.10	0.15	3.25	0.11	0.46	5.07	0.60	0.15	3.25	0.06	0.41	4.47	Minimum
16	4.10	0.22	5.20	0.41	0.99	10.92	2.50	0.22	5.20	0.25	0.82	8.99	Maximum
16	2.80	0.22	5.20	0.28	0.85	9.35	1.50	0.22	5.20	0.15	0.71	7.78	Average
16	1.95	0.22	5.20	0.20	0.76	8.33	1.10	0.22	5.20	0.11	0.66	7.29	Minimum
20	7.40	0.35	7.75	0.74	1.62	17.86	4.10	0.35	7.75	0.41	1.26	13.87	Maximum
20	3.95	0.35	7.75	0.40	1.25	13.70	2.20	0.35	7.75	0.22	1.05	11.57	Average
20	2.80	0.35	7.75	0.28	1.12	12.30	1.90	0.35	7.75	0.19	1.02	11.21	Minimum

30	12.35	0.80	15.30	1.24	2.97	32.66	9.00	0.80	15.30	0.90	2.60	28.60	Maximum
30	9.40	0.80	15.30	0.94	2.64	29.08	4.00	0.80	15.30	0.40	2.05	22.55	Average
30	5.20	0.80	15.30	0.52	2.18	24.00	3.40	0.80	15.30	0.34	1.98	21.82	Minimum
36	16.85	0.95	19.20	1.69	3.87	42.56	12.20	0.95	19.20	1.22	3.36	36.93	Maximum
36	12.00	0.95	19.20	1.20	3.34	36.69	5.80	0.95	19.20	0.58	2.65	29.18	Average
36	9.85	0.95	19.20	0.99	3.10	34.09	5.10	0.95	19.20	0.51	2.58	28.34	Minimum

Columns: 1—Water mains and fittings. 2—Excavating, laying, backfilling; overhead of foremen and watchmen. 3—Hauling pipe, fittings, etc.; investigating subsurface obstructions; operating valves. 4—Cost of cast iron pipe fittings, rope, timbers, etc. 5—10 per cent of labor cost (see chart 9). 6—10 per cent of summary of columns 2, 3, 4 and 5. 7—Total cost of installation. 8—Material excavated and subsurface obstructions encountered. *Maximum*—(a) Material excavated—50 per cent sandstone, granite or other rock, or (b) subsurface obstructions of such a nature that (a) would apply as to time and cost of work (industrial sections). *Average*—(a) Material excavated—loam, clay, gravel and deteriorated rock, or (b) subsurface obstructions of such a nature that (a) would apply as to time and cost of work (industrial and business sections). *Minimum*—(a) Material excavated—sand, loam and gravel, or (b) sub-surface obstructions of such nature as found in typical residential public highways.

TABLE 3

Hourly rate of pay and water works material costs

HOURLY RATE OF PAY				MATERIAL COSTS					
Title	Maximum	Average	Minimum	Material	Unit price	Material	Unit price.	Material	Unit price
Water pipe construction foreman	$0.72	$0.63	$0.56	Class B cast iron pipe	$71.00 per ton	¾-inch wrought iron lead lined pipe	$0.22 per foot	¾-inch lead tail	$2.46
Labor foreman	.54	.54	.54	Cast iron fittings	140.00 per ton	1-inch wrought iron lead lined pipe	.30 per foot	1-inch lead tail	3.30
Handy man	.55	.525	.50	Coal oil	.115 per gallon	2-inch wrought iron lead lined pipe	.70 per foot	2-inch lead tail	12.49
Pipe caulker	.50	.50	.50	Gasoline	.235 per gallon	¾-inch corporation	1.34	¾-inch curb stops	1.18
Special laborer	.45	.425	.40	Lead	.055 per pound	1-inch corporation	1.45	1-inch curb stops	1.80
Night watchman	.38	.38	.38	Lumber	.045 board foot	2-inch corporation	7.84	2-inch curb stops	7.34
				Packing rope	.09 per pound	3-foot curb stop box	1.58	5-foot curb stop box	1.95

Note: $71.00 per ton for class "B" cast iron pipe refers to unit purchase price in year 1920. Present unit price for class "B" cast iron pipe is $61.00 per ton. Other unit prices refer to purchases made in 1921.

TABLE 4

Method of ascertaining depreciation charges on standard tools equipment of a water pipe construction foreman—construction sub-division

DESCRIPTION OF A WATER PIPE CONSTRUCTION FOREMAN'S EQUIPMENT FOR AN AVERAGE SIZE CORPS OF 14 MEN	PROBABLE LIFE OF EQUIPMENT	ORIGINAL COST OF EQUIPMENT	DEPRECIATION COST PER DAY OF EQUIPMENT
1 Watchman's house	5 years	$255.00	$0.17
1 First-aid cabinet (complete)	3 months	15.00	0.20
1 Oil stove	1 year	6.00	0.02
2 Tool boxes	2 years	50.00	0.08
15 Picks	6 months	17.00	0.11
15 Long-handle shovels	6 months	39.75	0.26
4 Mattocks	6 months	8.00	0.05
2 Digging bars	6 months	6.80	0.05
2 Steel bars	6 months	7.60	0.05
6 Wall points	3 months	12.00	0.16
10 Ditch jacks	1 year	50.00	0.17
4 Sledge hammers	3 months	8.00	0.10
4 4½ pound hammers	3 months	5.00	0.07
1 Adz	6 months	2.00	0.01
1 Axe	6 months	2.00	0.01
4 Gallous keys	1 year	12.40	0.04
2 Socket keys	1 year	6.00	0.02
4 Hydrant keys	1 year	6.32	0.02
2 N. S. hydrant keys	1 year	3.00	0.01
2 Corporation keys	1 year	4.50	0.02
2 Curb stop keys	1 year	2.00	0.01
12 Handle diamond point tools	3 months	12.10	0.16
6 Finger diamond point tools	3 months	9.00	0.12
5 Pipe cutters (handle)	3 months	6.25	0.08
6 Pipe cutters	3 months	10.50	0.14
5 Breaking-out chisels	3 months	7.50	0.10
3 Long chisels	3 months	4.80	0.07
10 Roping tools	9 months	11.00	0.05
3 Lead runners	6 months	45.00	0.30
1 Hauck lead melting furnace	2 years	88.35	0.15
3 9-inch ladles	1 year	9.00	0.03
1 6-inch ladle	1 year	2.00	0.01
12 Handle caulking tools	3 months	12.00	0.16
3 Sets finger caulking tools	6 months	36.00	0.24
1 ¾-inch Mueller tapping machine	1 year	180.00	0.60
3 Saddles	1 year	9.00	0.03
1 Vise	1 year	5.50	0.02
2 Three-wheel pipe cutters	9 months	24.00	0.12
1 Set stocks and dies	6 months	15.00	0.10

TABLE 4—*Concluded*

DESCRIPTION OF A WATER PIPE CONSTRUCTION FOREMAN'S EQUIPMENT FOR AN AVERAGE SIZE CORPS OF 14 MEN	PROBABLE LIFE OF EQUIPMENT	ORIGINAL COST OF EQUIPMENT	DEPRECIATION COST PER DAY OF EQUIPMENT
1 Ditch ratchet (complete)	1 year	$25.00	$0.08
3 Monkey wrenches	1 year	8.00	0.03
4 Stillson wrenches	1 year	11.32	0.04
2 Rasps	6 months	2.50	0.02
1 Oiler	2 years	2.50	0.01
3 Rammers	2 years	7.00	0.01
1 Wood chisel	1 year	5.80	0.02
1 8-inch single block	6 months	3.40	0.02
1 8-inch double block	6 months	6.00	0.04
1 Hand saw	6 months	2.50	0.02
1 Cross-cut saw	6 months	8.35	0.06
1 Chain	6 months	2.40	0.02
1 Street broom	1 year	1.00	0.01
3 Buckets	3 months	1.95	0.02
10 Pairs rubber boots	6 months	50.00	0.33
15 Slickers	1 year	75.00	0.25
15 Standards	1 year	30.15	0.10
1 50-foot tape	6 months	3.00	0.02
10 Red flags	3 months	5.00	0.07
Total			$5.29

From the life and original cost the depreciation for each water pipe construction foreman's equipment is $5.29 per day.

Note: Method of ascertaining the percentage of labor cost to apply to installation of water mains to cover the depreciation and loss of tools is shown on chart 9.

vaults. The costs per foot of installation of water supply services include tapping the main, insertion of the corporation, lead tail, lead lined pipe, curb stop and curb stop box. The installation of cast iron water supply services includes the insertion of the sleeve and three-way, cast iron pipe, valve and roadway box. The cost of installation of valves includes the cost of the valve, lead, blocking, packing, rope, etc. The cost of erection of the vault for valve includes the labor, material, depreciation and overhead. The cost of the installation of fire hydrants includes the cost of the insertion of three-way and sleeve, cast iron pipe, valve and fire hydrant.

TABLE 5

Method of ascertaining per cent labor cost per foot water mains installed covering loss and depreciation of tools.

SIZE	NUMBER OF MEN IN WATER PIPE CONSTRUCTION CORPS	NUMBER OF FEET WATER MAIN INSTALLED BY CORPS PER DAY	DEPRECIATION COST OF TOOLS PER FOOT OF WATER MAINS INSTALLED		AVERAGE COST PER FOOT OF WATER MAINS COVERING LOSS AND BREAKAGE OF TOOLS	LABOR COST PER FOOT OF WATER MAINS INSTALLED	PERCENTAGE OF LABOR COST PER FOOT OF WATER MAINS INSTALLATION APPLIED TO DEPRECIATION AND LOSS OF TOOLS	
(1)	(2)	(3)	(4a)	(4b)	(5)	(6)	(7a)	(7b)
inches								*per cent*
6	14	75	$\frac{\$5.29}{75}$	$.07	$0.02	$0.90	$\frac{\$.09}{.90}$	10.0
10	14	60	$\frac{5.29}{60}$	.09	0.03	1.30	$\frac{.12}{1.30}$	9.2
16	14	30	$\frac{5.29}{30}$	.18	0.04	2.80	$\frac{.22}{2.80}$	7.9
20	14	25	$\frac{5.29}{25}$	.21	0.05	3.95	$\frac{.26}{3.95}$	6.7
30	14	10	$\frac{5.29}{10}$	.53	0.07	9.40	$\frac{.60}{9.40}$	6.3

Column 1 —Size of cast iron pipe class "B" and necessary cast iron fittings for a typical public highway.

Column 2 —Average sized water pipe construction corps.

Column 3 —Average number of feet of water mains installed by a corps of of size noted in column 2.

Column 4a—Fraction equals total depreciation of tools divided by number of feet of water mains installed per day. (See table 4 for depreciation on each tool.)

Column 4b—Quotient of column 4a equals depreciation cost of tools per foot of water mains installed.

Column 5 —Loss and breakage of petty tools such as chisels, small caulking tools, etc.

Column 6 —Labor cost per foot of water mains installed. "Installation" includes excavation, laying and back-filling.

Column 7a—Fraction equals $\dfrac{\text{depreciation cost plus breakage and loss of petty tools}}{\text{Labor cost per foot}}$

or $\dfrac{\text{(Columns 4b+5)}}{\text{Column 6}}$

Column 7b—Percentage of total labor cost that covers the depreciation, loss and breakage of tools.

TABLE 6

Method of ascertaining overhead charge against each construction order by the construction sub division of engineering and construction division

WATER DEPARTMENT DIVISIONS AND SUB DIVISIONS	SALARIES OF EMPLOYEES	PERCENTAGE OF SALARIES CHARGED AGAINST CONST. ORDER	SALARIES CHARGED AS OVERHEAD
		per cent	
Executive Division Water Department....	$16,100.00	11.11	$1,788.88
Auditing Division, Water Department....	16,800.00	11.11	1,866.66
Executive Sub division, Engineering and Construction Division..................	10,400.00	33.33	3,466.66
Clerical Sub division, Engineering and Construction Division..................	21,870.00	33.33	7,290.00
Construction Sub division, Engineering and Construction Division			
1 Assistant civil engineer, construction	2,500.00	100.00	2,500.00
2 Junior civil engineers...............	3,300.00	100.00	3,300.00
3 Engineering aids.....................	3,550.00	100.00	3,550.00
1 Junior clerk (cost accountant work)	1,200.00	100.00	1,200.00
1 Timekeeper........................	1,400.00	100.00	1,400.00
Engineering and Construction drafting at Bureau of Drafting..................	8,137.80	100.00	8,137.80
Total salaries charged as overhead..........................			$34,500.00
Water Department Miscellaneous Appropriations (buildings, equipment, autos, instruments, stationery, etc.............	$94,500.00	11.11	$10,500.00
Grand total of salaries and miscellaneous appropriations charged as overhead....................................			$45,000.00

Total expenditures of Construction Subdivision of Engineering and Construction Division is estimated at $450,000.00 for year 1921.

Percentage of overhead = $\frac{\$\ 45,000.00}{\$450,000.00}$ = 10 per cent.

LOCATION OF SUBSURFACE STRUCTURES IN PUBLIC HIGHWAYS

Figure 10 shows sections of public highways of various widths suggesting locations of subsurfaces so as to permit the use of trenching machines in almost all the public highways.

TABLE 7

Costs per foot of installation of water supply services in (66.0 feet public highway)

SIZE	HAND LABOR				
	Labor cost per foot (1)	Material cost per foot (2)	Depreciation cost per foot (3)	Overhead cost per foot (4)	Total cost per foot (5)
¾-inch wrought iron lead lined pipe....	$0.27	$0.66	$0.03	$0.10	$1.06
1-inch wrought iron lead lined pipe....	.30	.78	.03	.11	1.22
2-inch wrought iron lead lined pipe....	.40	2.19	.04	.26	2.89
3-inch class B cast iron pipe..........	.45	2.15	.05	.27	2.92
4-inch class B cast iron pipe..........	.50	2.57	.05	.31	3.43

Cost of installation of valves in (66.0 feet public highway)

SIZE	HAND LABOR					
	Labor cost (1)	Material cost (2)	Depreciation cost (3)	Overhead cost (4)	Cost of erection of vault	Total cost (5)
inches						
6	$5.30	$31.20	$0.53	$3.70		$40.73
10	6.20	74.95	.62	8.18		89.95
12	6.70	92.80	.67	10.02		110.19
16	8.20	131.86	.82	14.09	$126.59	281.56
20	15.20	281.95	1.52	29.87	169.18	497.72
30	32.10	462.14	3.21	49.75	233.08	780.28
36	41.10	1430.10	4.11	147.53	317.68	1940.52

Cost of installation of fire hydrants in (66.0 feet public highway)

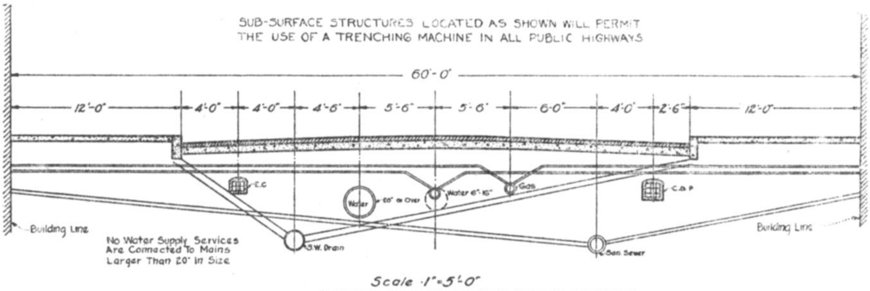
SIZE	HAND LABOR				
	Labor cost (1)	Material cost (2)	Depreciation cost (3)	Overhead cost (4)	Total cost (5)
inches					
6	$47.65	$106.75	$4.77	$15.92	$175.09

Standard vaults for valves

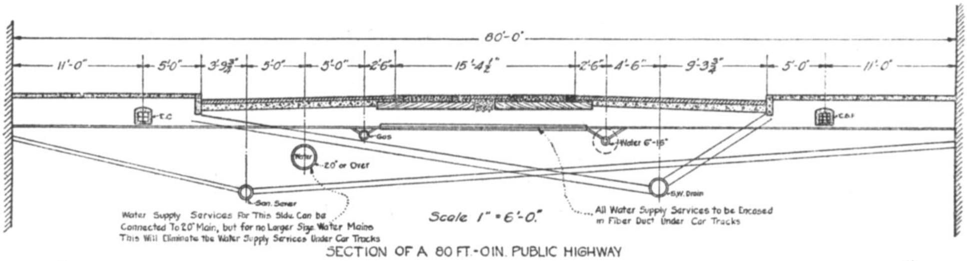
SIZE OF VALVES	SIZE OF VAULTS			THICKNESS OF BRICK WALLS	THICKNESS OF RE-ENFORCED CONCRETE SLAB	DIAMETER OF MANHOLE FRAME
	Inside length	Inside width	Average depth			
inches	*feet*	*feet*	*feet*	*inches*	*inches*	*inches*
16	4.5	4.5	5.5	9	6	24
20	8.0	4.5	6.0	9	6	24
30	11.0	5.5	6.5	13	7	30
36	13.0	6.0	7.0	13	7	30

Column 1—Excavation, laying, backfilling; overhead of foremen and watchmen. Column 2—Cost of cast iron pipe, fittings, lead, rope, timber, etc. Column 3—10 per cent of the labor cost (tools and equipment, see table 5). Column 4—10 per cent of the summary of columns 1, 2 and 3. Column 5—total cost of installation.

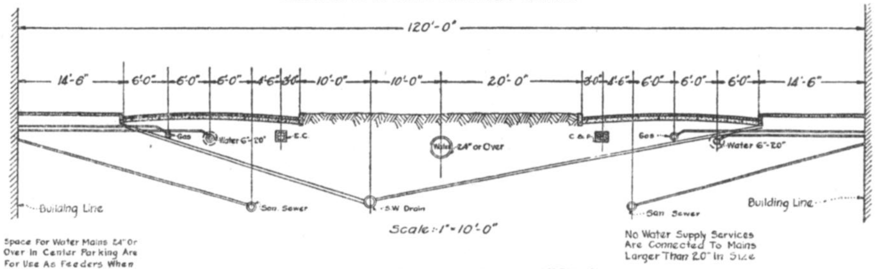
These sections also show the possibility of placing public utilities structures in a definite location so as to safeguard against interruption of service. Should municipalities adopt a standard of location for subsurface structures in public highways, especially in the newer sections of cities, it will have a tendency to decrease the construction and maintenance costs.


SUB-SURFACE STRUCTURES LOCATED AS SHOWN WILL PERMIT THE USE OF A TRENCHING MACHINE IN ALL PUBLIC HIGHWAYS
60'-0"
12'-0"
4'-0"
4'-0"
4'-6"
5'-6"
5'-6"
6'-0"
4'-0"
2'-6"
12'-0"
E.C
Water
20" or Over
Water 6"-16"
Gas
C.&P.
Building Line
Building Line
No Water Supply Services Are Connected To Mains Larger Than 20" In Size
S.W. Drain
San. Sewer
Scale 1"=5'-0"

SECTION OF A 60 FT.-0 IN PUBLIC HIGHWAY


80'-0"
11'-0"
5'-0"
3'-9¾"
5'-0"
5'-0"
2'-6"
15'-4½"
2'-6"
4'-6"
9'-3¾"
5'-0"
11'-0"
E.C
C.&P.
Gas
Water 6"-16"
Water
20" or Over
San. Sewer
S.W. Drain
Water Supply Services For This Side Can be Connected To 20" Main, but for no Larger Size Water Mains This Will Eliminate the Water Supply Services Under Car Tracks
Scale 1"=6'-0"
All Water Supply Services to be Encased in Fiber Duct Under Car Tracks

SECTION OF A 80 FT.-0 IN. PUBLIC HIGHWAY



SECTION OF A 120 FT.-0 IN PUBLIC HIGHWAY
WITH A CENTER PARKING

FIG. 10

The large amount of work completed by the Water Department has been due to the fact that Mr. Wm. A. Megraw, Water Engineer, has encouraged the purchase of machinery for use in the construction of water mains which procedure was inaugurated by Mr. Walter E. Lee, the former incumbent.

Due acknowledgment is given herewith to the work of Mr. C. A. Warren, Assistant Civil Engineer In Charge of the Construction Subdivision of the Engineering and Construction Division, and to his assistant, Mr. Maurice Goldstein, Junior Civil Engineer, for the cost data furnished.

THE CUTTING OF A 60-INCH CAST IRON (CLASS "B") WATER MAIN AT NORTH AVENUE AND OAK STREET WITH OXY-ACETYLENE TORCH

The proposed changes in the distribution system at North Avenue and Oak Street required the removal of a 60 inch by 30 inch three-way and inserting of a 60 inch by 48 inch three-way and connections. As the operations of the Water Department were retarding the paving of the street, a method quicker than cutting the 60-inch cast iron pipe by hand labor was desired. An oxy-acetylene torch and operator were obtained through the local sales engineer of the Davis-Bournonville Company, and the cutting of the cast iron pipe was started immediately. The progress of the cut varied from 0.63 inch a minute to 1.3 inches a minute, the average being 0.7 inch a minute. The thickness of the cast iron pipe was 1.7 inches. Upon investigating the cut edges, small cracks were discovered around the entire circumference at intervals of 1.5 feet extending from ½ inch to 1½ inches from the face of the cut. This necessitated the removal of the pipe and the insertion of a new piece of 60 inch main. The new main was cut on the surface by hand labor, thus affording a direct comparison of the cutting of cast iron pipe by hand labor and with the oxy-acetylene torch. The following results were obtained. The cost of cutting the 60 inch pipe (2 cuts) by hand labor was $232.52 including labor, overhead, depreciation and the cost of sharpening the tools. The cost of cutting the cast iron pipe (2 cuts) with the oxy-acetylene torch was $104.23 including labor, fuel consumed, depreciation and overhead, thus resulting in a saving of 55.2 per cent. The time saved was 62.1 per cent.

As the result of research work now being conducted by the engineers of the Davis-Bournonville Company I am convinced that a practical way will be found for cutting cast iron pipe economically and quickly with the oxy-acetelene torch.